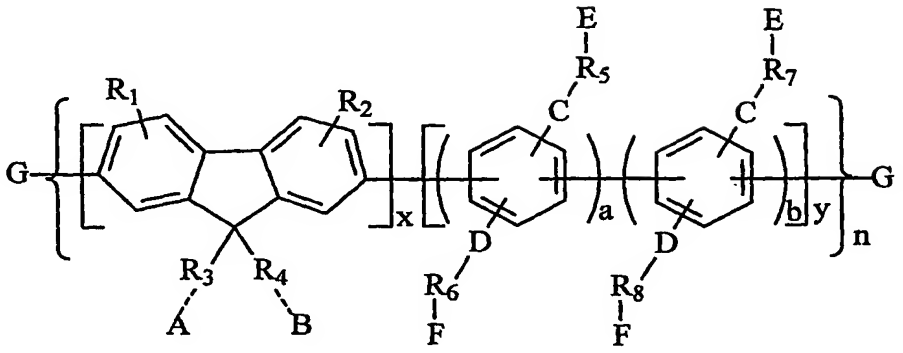
Claims

The claims defining this invention are as follows:

1. A conjugated polymer of the formula:



wherein:

- R_1 and R_2 are identical or different and are each H, a straight or branched alkyl, alkoxyl, ester groups or cyclic crown ether groups having from 1 to about 22 carbon atoms;
- A, B, E and F are identical or different and are each H, SiR'R" or NR'R" (wherein at least one of A, B, E or F is NR'R"); R' and R" are independently selected from the group consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, (C3 to C10) cycloalkyl groups;
- C and D are identical or different and are each H (but can not both be H), O, S, CO, COO, CRR', NR', SiR'R", wherein R' and R" are as defined above;
- R_3 and R_4 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms;
- R_5, R_6, R_7 and R_8 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms and which may contain one or more aromatic groups, substituted or unsubstituted aromatic moieties;
- G is hydrogen, halogen, boronic acid, boronate radical or an aryl moiety;

- a and b are independent and each is a number from 0 to about 100, wherein if a is 0, b is a number from 1 to about 100 and if b is 0, a is a number from 1 to about 100;
- x and y are also independent and each is a number from 1 to about 100; and
- n is a number from 1 to about 1000.

2. A polymer according to claim 1, wherein the polymers are homopolymers.

3. A polymer according to claim 1, wherein the polymers are random copolymers.

4. A polymer according to claim 1, wherein the polymers are alternated copolymers.

5. A polymer according to any one of the claims 1 to 4, wherein R_1 and R_2 are H or straight or branched alkyl groups having from 1 to about 12 carbon atoms.

6. A polymer according to any one of claims 1 to 4, wherein R_1 and R_2 are alkoxyl groups with from 1 to about 12 carbon atoms.

7. A polymer according to any one of claims 1 to 4, wherein R' and R" are alkyl or alkoxyl groups having from 1 to 4 carbon atoms.

8. A polymer according to any one of claims to 4, wherein A, B, E and F are independently selected from hydrogen or NR'R" (but not all can be hydrogen).

9. A polymer according to any one of claims 1 to 4, wherein R_3 and R_4 are linear or branched aliphatic chains, having from 1 to 4 carbon atoms, containing one or more heteroatoms and/or one or more aromatic groups.

10. A polymer according to any one of claims 1 to 4, wherein R_3 and R_4 are alkoxyl groups having from 2 to about 12 carbon atoms.

11. A polymer according to any one of claims 1 to 4, wherein R_5, R_6, R_7 and R_8 are linear or branched aliphatic chains, having from 1 to about 8 carbon atoms, containing one or more heteroatoms.

12. A polymer according to any one of claims 1 to 4, wherein R_5, R_6, R_7 and R_8 are alkoxyl groups having from 2 to about 12 carbon atoms.

13. A polymer according to any one of claims 1 to 4, wherein x and y are each a number between 1 and 20.

14. A polymer according to claim 13, wherein x and y are each a number between 1 and 10.

15. A polymer according to any one of claims 1 to 4, wherein a and b are each a number between 0 and 10.

16. A polymer according to any one of claims 1 to 4, wherein n is a number between 1 and about 50.

17. A polymer according to any one of claims 1 to 4, wherein G is an aryl moiety containing halogen, boronic acid or boronate radical.

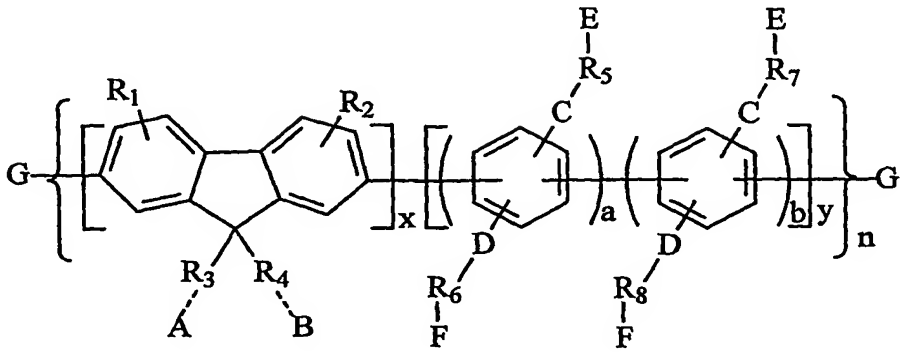
18. A polymer according to any one of claims 1 to 4, wherein G is hydrogen or an unsubstituted or substituted aryl moiety which does not contain halogen, boronic acid or boronate radical.

19. A polymer according to any one of claims 1 to 4, wherein the linkage between fluorene and phenylene is on the 1 and 4 positions.

20. A polymer according to any one of claims 1 to 4 having a backbone comprising extended phenylene units.

21. A polymer according to any one of claims 1 to 4 having a backbone comprising extended fluorene units.

22. A method of increasing the solubility, in polar solvents, of a conjugated polymer of the formula:



wherein:

- R_1 and R_2 are identical or different and are each H, a straight or branched alkyl, alkoxyl, ester groups or cyclic crown ether groups having from 1 to about 22 carbon atoms;
- A, B, E and F are identical or different and are each H, SiR'R" or NR'R" (wherein at least one of A, B, E or F is NR'R"); R' and R" are independently selected from the group consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, (C3 to C10) cycloalkyl groups;
- C and D are identical or different and are each H (but can not both be H), O, S, CO, COO, CRR', NR', SiR'R", wherein R' and R" are as defined above;
- R_3 and R_4 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms;
- R_5, R_6, R_7 and R_8 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms and which may contain one or more aromatic groups, substituted or unsubstituted aromatic moieties;
- G is hydrogen, halogen, boronic acid, boronate radical or an aryl moiety;
- a and b are independent and each is a number from 0 to about 100, wherein if a is 0, b is a number from 1 to about 100 and if b is 0, a is a number from 1 to about 100;
- x and y are also independent and each is a number from 1 to about 100; and

- n is a number from 1 to about 1000;

by quaternizing terminal amino groups of the polymer.

23. A method according to claim 22, wherein said quaternization is effected by treating the polymer with an alkyl bromide.

24. A method according to claim 23, wherein the alkyl bromide is bromoethane.

25. A method according to claim 24, wherein the polymer is treated with bromoethane by stirring the polymer with bromoethane in dimethyl sulfoxide (DMSO) and tetrahydrofuran (THF).

26. A method according toclaim 25, wherein the ratio of DMSO and THF is about 1:4, and the stirring is effected at about 50°C for about 5 days.

27. A method according to claim 24, wherein the polymer is treated with bromoethane by stirring the polymer with bromoethane in tetrahydrofuran.

28. A method according to claim 27, wherein the stirring is effected at about room temperature for about 24 hours.

29. A method according to any one of claims 25 to 28, comprising the further steps of:

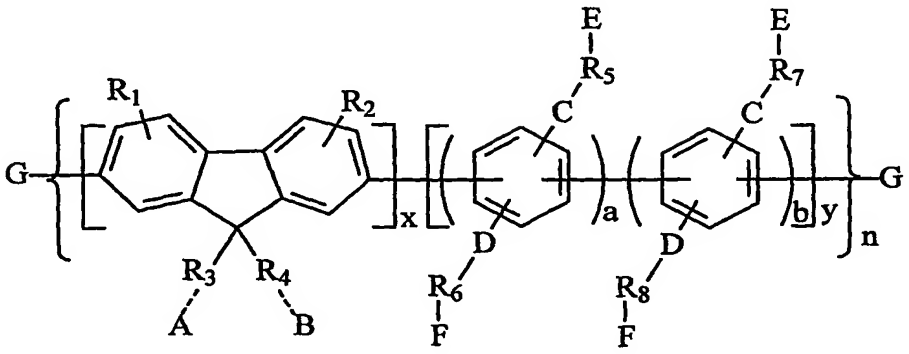
- evaporating the solvents;
- precipitating the quaternized polymer;
- washing the polymer; and
- drying the polymer.

30. A method according to claim 29, wherein the polymer is precipitated by adding acetone followed by centrifugation.

31. A method according to claim 29 wherein the washing is effected with chloroform and/or acetone.

32. A method of forming a conjugated cationic polymer, having a desired solubility in a given solvent, said method comprising:

- providing a polymer of the formula:



wherein:

- R_1 and R_2 are identical or different and are each H, a straight or branched alkyl, alkoxyl, ester groups or cyclic crown ether groups having from 1 to about 22 carbon atoms;
- A, B, E and F are identical or different and are each H, SiR'R" or NR'R" (wherein at least one of A, B, E or F is NR'R"); R' and R" are independently selected from the group consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, (C3 to C10) cycloalkyl groups;
- C and D are identical or different and are each H (but can not both be H), O, S, CO, COO, CRR', NR', SiR'R", wherein R' and R" are as defined above;
- R_3 and R_4 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms;
- R_5, R_6, R_7 and R_8 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms and which may contain one or more aromatic groups, substituted or unsubstituted aromatic moieties;
- G is hydrogen, halogen, boronic acid, boronate radical or an aryl moiety;

- a and b are independent and each is a number from 0 to about 100, wherein if a is 0, b is a number from 1 to about 100 and if b is 0, a is a number from 1 to about 100;
- x and y are also independent and each is a number from 1 to about 100; and
- n is a number from 1 to about 1000;

- determining a desired solubility of the polymer in the given solvent; and

- quaternizing terminal amino groups of the polymer to an extent necessary to cause the polymer to have the desired solubility.

33. A method according to claim 32, wherein between about 30% and about 80% of the terminal amino groups undergo quaternization.

34. A method according to claim 32, wherein said quaternization is effected by treating the polymer with an alkyl halide.

35. A method according to claim 34, wherein the alkyl halide is bromoethane.

36. A method according to claim 35, wherein the polymer is treated with bromoethane by stirring the polymer with bromoethane in dimethyl sulfoxide (DMSO) and tetrahydrofuran (THF).

37. A method according to claim 36, wherein the ratio of DMSO and THF is about 1:4, and the stirring is effected at about 50°C for about 5 days.

38. A method according to claim 35, wherein the polymer is treated with bromoethane by stirring the polymer with bromoethane in tetrafurohydran.

39. A method according to claim 38, wherein the stirring is effected at about room temperature for about 24 hours.

40. A method according to any one of claims 36 to 39, comprising the further steps of:

- evaporating the solvents;

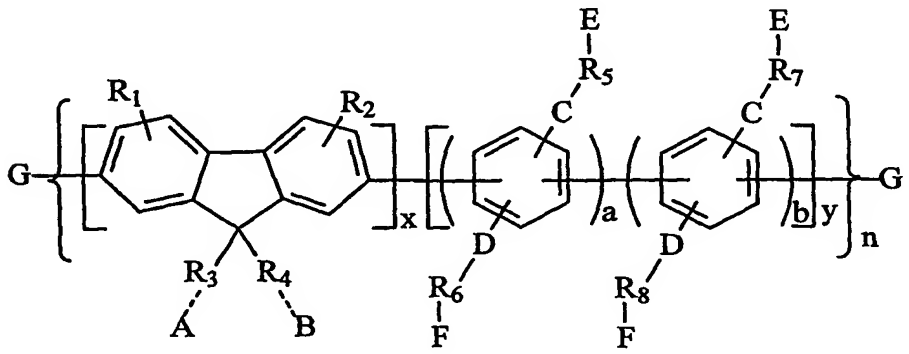
- precipitating the quaternized polymer;
- washing the polymer; and
- drying the polymer.

41. A method according to claim 40, wherein the polymer is precipitated by adding acetone followed by centrifugation.

42. A method according to claim 40, wherein the washing is effected with chloroform and/or acetone.

43. A method of forming a conjugated cationic polymer, said method comprising:

- providing monomer precursors of a polymer of the formula:



wherein:

- R_1 and R_2 are identical or different and are each H, a straight or branched alkyl, alkoxyl, ester groups or cyclic crown ether groups having from 1 to about 22 carbon atoms;
- A, B, E and F are identical or different and are each H, SiR'R" or NR'R" (wherein at least one of A, B, E or F is NR'R"); R' and R" are independently selected from the group consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, (C3 to C10) cycloalkyl groups;
- C and D are identical or different and are each H (but can not both be H), O, S, CO, COO, CRR', NR', SiR'R", wherein R' and R" are as defined above;

- R_3 and R_4 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms;
- R_5, R_6, R_7 and R_8 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms and which may contain one or more aromatic groups, substituted or unsubstituted aromatic moieties;
- G is hydrogen, halogen, boronic acid, boronate radical or an aryl moiety;
- a and b are independent and each is a number from 0 to about 100, wherein if a is 0, b is a number from 1 to about 100 and if b is 0, a is a number from 1 to about 100;
- x and y are also independent and each is a number from 1 to about 100; and
- n is a number from 1 to about 1000;

- quaternizing terminal amino groups of the monomer precursors; and

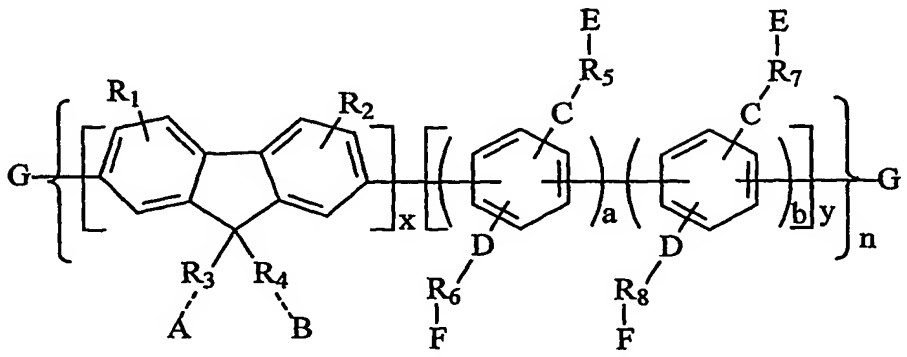
- synthesizing the cationic polymer from said quaternized monomer precursors.

44. A method according to claim 43, wherein said synthesis is effected by the Suzuki coupling reaction.

45. A method according to claim 43, further including the steps of determining the desired solubility of the cationic polymer and calculating the amount of monomer precursors required to form a cationic polymer having the desired solubility.

46. A method according to claim 43, further including the step of determining the desired solubility of the cationic polymer, and wherein the terminal amino groups are quaternized to a degree sufficient to result in the cationic polymer having the desired solubility.

47. A conjugated cationic polymer of the formula:

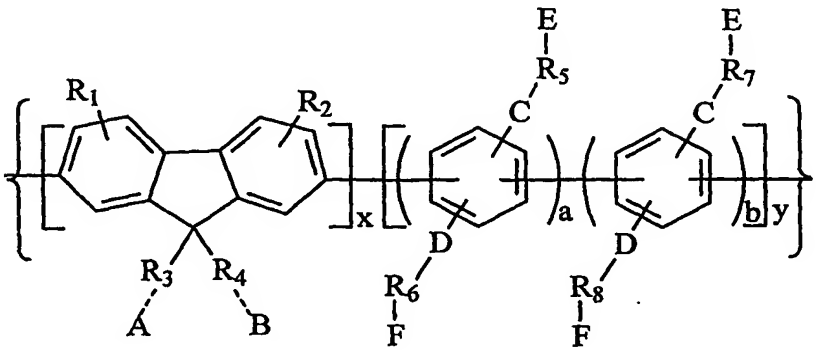


wherein:

- R_1 and R_2 are identical or different and are each H, a straight or branched alkyl, alkoxyl, ester groups or cyclic crown ether groups having from 1 to about 22 carbon atoms;
- A, B, E and F are identical or different and are each H, SiR'R" or NR'R" (wherein at least one of A, B, E or F is NR'R"); R' and R" are independently selected from the group consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, (C3 to C10) cycloalkyl groups;
- C and D are identical or different and are each H (but can not both be H), O, S, CO, COO, CRR', NR', SiR'R", wherein R' and R" are as defined above;
- R_3 and R_4 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms;
- R_5, R_6, R_7 and R_8 are identical or different and are independently selected from linear, branched or cyclical saturated or unsaturated aliphatic moieties which may contain one or more heteroatoms and which may contain one or more aromatic groups, substituted or unsubstituted aromatic moieties;
- G is hydrogen, halogen, boronic acid, boronate radical or an aryl moiety;
- a and b are independent and each is a number from 0 to about 100, wherein if a is 0, b is a number from 1 to about 100 and if b is 0, a is a number from 1 to about 100;

- x and y are also independent and each is a number from 1 to about 100; and
- n is a number from 1 to about 1000;

said cationic polymer comprising repeating units of the formula:



wherein:

(a) R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, C, D, a, b, x and y are as defined in claim 1; and

(b) in at least one of the repeating units, at least one of A, B, E and F is NR'R"R"', wherein R', R" and R"' are independently selected from the groups consisting of hydrogen, unbranched or branched alkyl or alkoxyl groups having 1 to about 12 carbon atoms, and (C_3 to C_{10}) cycloalkyl groups.

48. A cationic polymer according to claim 47, wherein at least one of R', R" and R"' is hydrogen.

49. A cationic polymer according to claim 48, wherein at least one of A, B, E and F is ammonium.

50. A cationic polymer, according to claim 49, wherein the ammonium has been quaternized from at least one amino substituent of the polymer.

51. A cationic polymer according to claim 49 wherein, in more than one of the repeating units, at least one of A, B, E and F is ammonium.

52. A cationic polymer according to claim 51 wherein, in more than one of the repeating units, more than one of A, B, E and F is ammonium.

53. A cationic polymer according to claim 50 wherein between about 30% and about 60% of the amino substituents in said polymer have been quaternized to ammonium.

54. A conjugated cationic polymer formed according to the method of any one of claims 43 to 46.

55. A conjugated cationic polymer substantially as hereinbefore described with reference to any one or more of the examples.

56. A salt comprising a conjugated cationic polymer according to any one of claims 47 to 55.

57. An ionic composition comprising a cationic polymer according to any one of claims 47 to 55.

58. A method of increasing the solubility, in polar solvents, of a polymer of any one of claims 1 to 21, said method being substantially as hereinbefore described with reference to any one or more of the examples.

59. A method of forming a conjugated cationic polymer, having a desired solubility in a given solvent, said method being substantially as hereinbefore described with reference to any one or more of the examples.